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RB25-207 The Spindle-Tuber Disease: One Cause of "Run-Out" Seed Potatoes

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The Spindle-Tuber Disease

One Cause of "Run-Out" Seed Potatoes

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Normal and Spindle-Tuber Triumph Potatoes

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SUMMARY

The spindle-tuber disease is one of the most prevalent potato diseases occurring in all parts of Nebraska. It has been found in all varieties tested. It does much damage to the potato crop, in that it reduces the yield and injures the market quality of the potatoes.

In the advanced stage it causes the development of elongated, cylindrical-shaped tubers with a large number of weak, shallow, or bulging eyes. In colored varieties the color is lighter and unevenly developed The plants are more or less dwarfed and have a very erect and stiff habit of growth. The leaves are somewhat small and narrow and are folded up along the midrib and develop a wavy margin.

The disease is carried over in the seed tubers. It is of an infectious nature and is transmitted from diseased to healthy plants by insects. Under certain conditions it spreads very rapidly. Lots exposed to the disease quite commonly become infected to the extent of 10 to 25 per cent in one year, but 80 to 100 per cent infection has been observed. This disease is capable of ruining a lot of seed for commercial production in from one to three years.

The disease seems to spread more rapidly in irrigated than in dry land fields. In eastern Nebraska it seems to develop less extensively in straw mulched than in cultivated potatoes. Late planting exerts a slightly retarding effect upon the increase of the disease. Early harvesting is somewhat less effective.

The selection of good type potatoes from a severely infected strain is of no value in controlling the disease. Early and frequent roguing of lots containing a low percentage of the disease was an effective control measure. Roguing was not effective with lots that contained a high percentage of the disease.

Recommendations for the control of the disease are:

(a) Selection of a good strain of seed potatoes as free as possible from this and other diseases.

(b) Selection of the best type tubers for planting in a seed plat.

(c) Isolating this seed plat from all other potato fields by a distance of at least 300 feet.

(d) Roguing this plat severely, early, and frequently, removing all suspicious looking plants.

(e) Selection of tubers of best type produced in this plat for use in the seed plat the following year and using the remainder of the potatoes for the commercial planting.

The Spindle-Tuber Disease

One Cause of "Run-Out" Seed Potatoes

A plant disease known by the name of "spindle-tuber" is the cause of much of the "running-out" or degeneracy of seed potatoes that has commonly been attributed to unfavorable climatic or soil conditions. As the name indicates, this disease causes the tubers to be elongated or spindle-shaped. Such spindle-shaped or "run-out" tubers, when planted, produce plants that are weaker, more erect, and less productive than are those grown from healthy tubers. The disease is infectious and spreads very rapidly, frequently ruining both the seed and market quality of a seed lot in one or two seasons. It is classified with the general group of virus diseases, the cause of which is not known at the present time.

DISTRIBUTION OF THE DISEASE

This disease has been found to be present to a serious extent in all varieties of potatoes that were included in our variety trials. These represented 10 of the 12 recognized American variety groups of potatoes. At the present time there is no indication that any variety or strain is resistant or immune. All varieties seem to be equally susceptible to this disease.

The disease is quite generally distributed thruout the United States. It has been found in lots of seed potatoes secured from 12 of the important northern potato-producing states. It has also been found in nearly all lots—and to a serious extent in some cases—of potatoes produced in all the important potato-producing regions of Nebraska. In the irrigated regions of western Nebraska it is very common—more so than under dry land culture.

In 1917, when the experimental work upon which this bulletin is based was started, it was supposed that "running-out" of seed potatoes was the result of environmental conditions. During the course of the experiments it was discovered that the spindle-tuber disease was the cause of most of the "running-out."

This is a popular edition of Nebraska Research Bulletin 32, which, together with Research Bulletin 24, contains the detailed data upon which this bulletin is based.

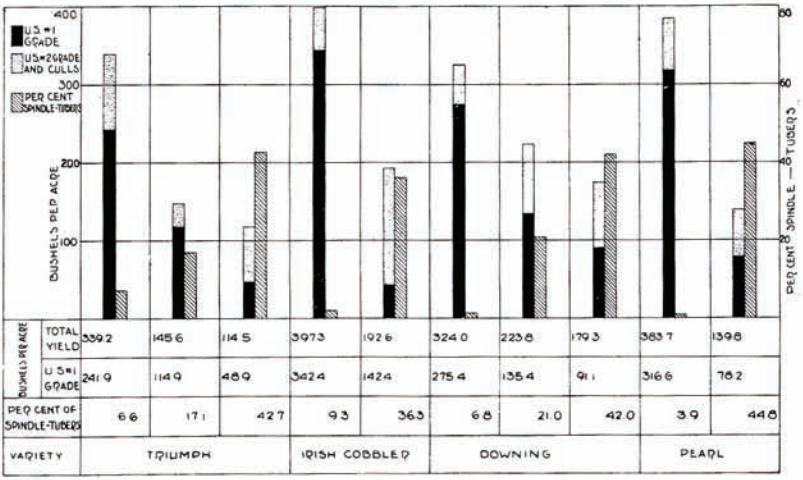
In 1923 the disease was found in every one of 113 lots of seed potatoes secured from irrigation farmers, and in many of these lots 90 to 100 per cent of the plants were affected. The long or "run-out" tubers now recognized as resulting from the disease have been noticed for many years in seed stock grown in southern and eastern Nebraska. Lots of seed grown at Lincoln for one year frequently show 40 to 60 per cent infection the second season.

During the last few years it has also developed as a serious problem in much of the western dry land seed stock. It has been reported in more than 95 per cent of the dry land fields inspected for certification during the last three years. The amount has ranged from just a trace to 40 per cent or more in the various fields. In the season of 1923 certification was refused on more than 1,100 acres of potatoes (or one-fifth of the total acreage inspected) because the amount of spindle-tuber exceeded 5 per cent. In 1924, however, the 131 lots that received the tuber inspection contained an average of only 2.63 per cent spindle-tubers. The dry land certified seed potato growers have held the disease in check by very rigid seed selection and by removing all visibly diseased plants from the field.

EFFECT UPON YIELD AND QUALITY

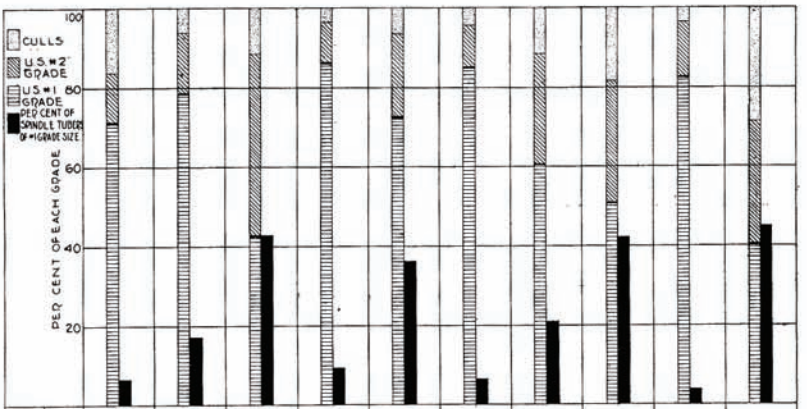
The yield of potatoes produced by an infected lot of seed is reduced in direct proportion to the percentage of infection and the degree of severity. Some idea of the extent of yield reduction as a result of the spindle-tuber disease is conveyed by Fig. 1. The figure shows the yield per acre secured in the same field from various lots and varieties of potatoes that were infected with spindle-tuber in varying degree. The percentages of harvested tubers that showed distinct spindle-tuber symptoms are used as a means of showing the relative infection.

The market quality of potatoes infected with the disease is very seriously impaired. The tubers are of abnormal shape and color. They have numerous eyes, frequently have growth cracks, and are somewhat smaller than potatoes from normal plants. The percentage of potatoes of No. 1 grade is lowered and at the same time the percentage of No. 2 grade and cull potatoes is increased. This is graphically shown in Fig. 2, for the lots of potatoes previously referred to. Not only is the percentage of grade No. 1 potatoes reduced, but the quality of this grade is relatively inferior,



		TRIUMPH			IRISH COBBLER		DOWNING			PEARL	
BUSHELS PER ACRE	TOTAL YIELD	339.2	145.6	114.5	397.3	192.6	324.0	223.8	179.3	383.7	139.8
	U.S.#1 GRADE	241.9	114.9	48.9	362.4	142.4	275.4	135.4	91.1	316.6	76.2
PER CENT OF SPINDLE-TUBERS		6.6	17.1	42.7	9.3	36.3	6.8	21.0	42.0	3.9	44.6
VARIETY		TRIUMPH			IRISH COBBLER		DOWNING			PEARL	

FIG. 1.—The total yield of potatoes decreases as the percentage of spindle-tuber increases



		TRIUMPH			IRISH COBBLER		DOWNING			PEARL	
PER CENT OF EACH GRADE	U.S.#1 GRADE	71.3	78.9	42.7	86.2	72.6	85.0	60.5	50.6	82.5	40.3
	U.S.#2 GRADE	12.5	14.6	45.7	8.9	20.6	10.6	27.9	30.8	13.6	30.8
	CULLS	16.2	6.3	11.6	4.9	6.8	4.4	11.6	18.4	3.9	28.9
PER CENT OF SPINDLE TUBERS OF #1 GRADE SIZE		6.6	17.1	42.7	9.3	36.3	6.8	21.0	42.0	3.9	44.6
VARIETY		TRIUMPH			IRISH COBBLER		DOWNING			PEARL	

FIG. 2.—The market grade and quality decrease as the percentage of spindle-tuber increases

because of the high percentage of these poor type or spindle-tubers. As a result, the price paid for such stock is frequently and justifiably less than that paid for potatoes of normal type.

With the combined reduction of yield and quality, resulting from this disease, it is not unusual for the financial returns per acre of potatoes to be reduced from 25 to 85 per cent or more. In the case of the Triumph potatoes, reported in Fig. 2, with potatoes at 50 cents per bushel, the returns from the sale of Grade No. 1 potatoes of the best lot would have been $124 while those from the poorest lot would have been only $24.50, or a loss of $99.50 per acre. In view of the fact that all Grade No. 1 tubers of the latter lot were spindle-tubers, they would have been sold for less than the estimated amount if sold on their merits. Proportional losses would result in commercial fields located in any part of the state. When earliness is a factor, an additional loss would result because plants infected with spindle-tuber are slower in coming thru the soil and in developing marketable tubers.

SYMPTOMS OF THE SPINDLE-TUBER DISEASE

In the advanced forms of the disease, the symptoms of spindle-tuber are very distinct but it is much more difficult to detect the disease with certainty when it is present in a very mild form. When combined in the same plant with other diseases as mosaic or leaf roll, the symptoms are often altered considerably.

SYMPTOMS IN THE TRIUMPH VARIETY

The symptoms of the disease are discussed in detail as they apply to the Triumph variety because this variety was used in most of the experiments and is the major variety in western Nebraska.

TUBER SYMPTOMS

Shape.[1]—Potatoes seriously infected with the spindle-tuber disease are very much elongated and cylindrical. They

[1] Environmental conditions sometimes are the cause of abnormally shaped tubers. Carefully controlled experiments have shown that tubers developed at high temperatures, in heavy soils, and in soils with a high moisture content are more elongated than those developed under the opposite conditions. Spindle-tuber potatoes raised at a low temperature are frequently better shaped than normal tubers produced at a high temperature. Consequently shape is not the most reliable spindle-tuber symptom when environmental conditions vary. Under such circumstances the eye and color symptoms are most reliable.

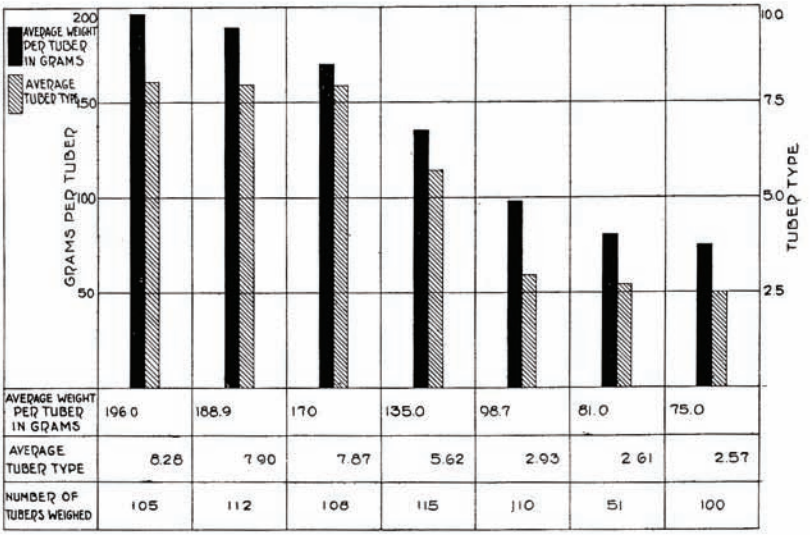
Tubers will also develop second growth, knobs, and growth cracks in quite a variety of styles. Such abnormally shaped tubers are generally the result of uneven growing conditions caused by variable temperature and moisture supply. An examination of the eyes will enable one to determine whether they are healthy or spindle-tubers. If tubers are not infected, they will produce normal type plants and tubers in spite of their very rough appearance.

are also pointed at the apical (bud) end. In the early stages the tubers are only slightly elongated, being somewhat blocky and tapering slightly. (See Fig. 3.) In the most advanced stages the tubers are often crooked or ill-shaped in other ways, and also seem very subject to growth cracks.

FIG. 3.—Effect of spindle-tuber upon the shape of Triumph potatoes. Tuber at left of upper row was healthy. All others were infected with spindle-tuber, the tuber at the right of the lower row showing the most advanced symptoms.

Size.—Tubers produced on diseased plants are almost always smaller than those produced on normal plants, especially so when the disease is relatively severe. This is effectively shown by the graph (Fig. 4) which is based on individual records of tubers, the progeny of seven groups of plants grown at Scottsbluff. The low numbers for tuber type represent poor type tubers showing advanced spindle-tuber symptoms, while the higher numbers represent good type tubers showing little or no symptoms of the spindle-tuber disease.

Number of Tubers per Plant.—Plants affected with the spindle-tuber disease generally produce fewer tubers per plant, varying of course with the severity of the disease. Seriously infected lots of potatoes produced an average number of 4.6 tubers per plant, with a mean tuber type of only



AVERAGE WEIGHT PER TUBER IN GRAMS	196.0	188.9	170	135.0	98.7	81.0	75.0
AVERAGE TUBER TYPE	8.28	7.90	7.87	5.62	2.93	2.61	2.57
NUMBER OF TUBERS WEIGHED	105	112	108	115	110	51	100

FIG. 4.—As spindle-tuber increases in severity in a strain of potatoes the size of the tubers decreases. (Approximately 450 grams equals 1 pound or 28 grams equals 1 ounce.)

2.6 (on basis of 10 for normal). In the same field supposedly healthy lots grown as checks produced 10.4 tubers per plant with an estimated tuber type of 7.5.

Color of Skin.—Very mildly infected tubers retain the normal color; but as the spindle-tuber disease advances, the distinct solid red color gradually fades to a lighter red or pink color, which eventually almost disappears. Finally considerable yellow color or a blotching of pink and yellow appears. This change in color does not occur until the disease is well established and causing distinct tuber elongation.

Tuber Eyes.—The eyes of tubers infected with the spindle-tuber disease are characteristically shallow. They are smaller than normal and have a general appearance of lack of vigor. As the disease advances, the eyes become more numerous and more shallow till finally they may be bulging. In this stage the eyes at the apical end (bud end) of seriously infected tubers are always raised instead of being sunken. The color of the skin within the eye remains practically unaltered even tho the remainder of the tuber has lost all of the normal color. The small weak eyes together with the

accompanying somewhat blocky tuber shape are the first tuber symptoms indicating the presence of the disease.

The tubers produced by infected vines frequently have conspicuous leaf scales. The "eyebrows" of infected tubers are much more conspicuous and angular than are those of normal tubers (Fig. 5).

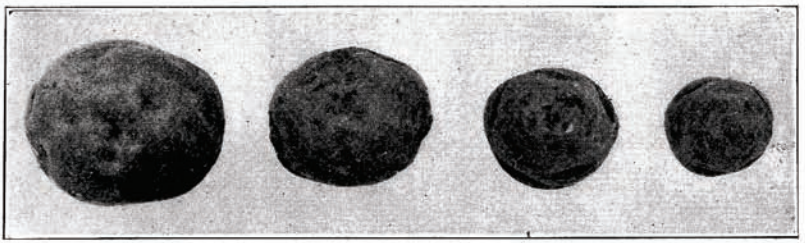


FIG. 5.—View of apical (bud) end of normal tuber at left and spindle tubers of varying degrees of infection at right, showing increase in the number and decrease in the size of the eyes and greater prominence of the "eyebrows" as the spindle-tuber disease becomes more severe.

PLANT SYMPTOMS

Rate of Growth.—Plants from tubers infected with the spindle-tuber disease sprout much more slowly than healthy tubers. Only 28.2 per cent of the plants from lots of seed seriously infected with spindle-tuber (average tuber type value 3.79) were thru the ground June 30 (23 days after planting), while by the same date, with lots of healthy certified seed potatoes, 96.7 per cent of the plants were thru. Many infected tubers do not sprout for 100 or more days and some never produce plants. This slow sprouting of infected tubers causes poor stands of plants of uneven size.

Thruout the entire growing season the diseased plants lack vigor and are smaller than normal plants. This lack of vigor is in direct proportion to the severity of the disease (Fig. 6).

Type of Plant Growth.—In addition to being somewhat smaller, plants infected with spindle-tuber have an erect and stiff habit of growth. They have very few stems per hill and these generally have no lateral branches. The leaves retain an erect habit of growth, making a rather sharp angle with the stem.

Leaves.—In infected plants the leaves are generally somewhat darker in color. As previously stated they have an

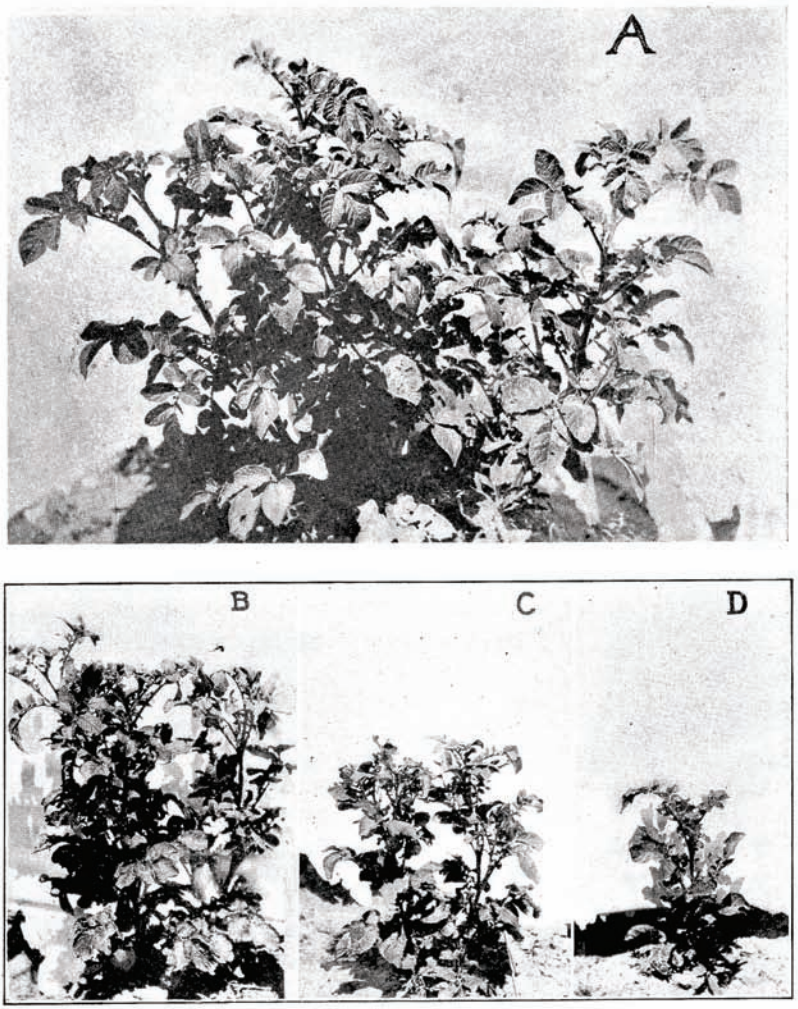


FIG. 6.—Effect of spindle-tuber on vine growth. A—normal plant; B, C and D diseased plants with D showing advanced symptoms.

erect and stiff appearance. They are folded upward along the midrib and show a distinct marginal waving. They are generally smaller and more narrow than normal leaves. The characteristic symptoms in the leaves are more distinctly manifested at high temperature, under drouthy conditions, and late in the season than under the opposite conditions.

SYMPTOMS IN OTHER VARIETIES

In all varieties the spindle-tuber disease causes the formation of elongated and cylindrical type tubers, varying in extent according to the degree of severity of the disease. The plant growth is also erect as described for the Triumph. In several of the varieties some symptoms develop more extensively than others.

FIG. 7.—Effect of spindle-tuber upon shape of Early Ohio potatoes. Tuber in upper row at left was a healthy tuber, all others were infected with spindle-tuber, with tuber in lower row at right showing advanced symptoms.

Early Ohio.—Infection in this variety results in extreme tuber elongation,—tubers sometimes being 4 or 5 times longer than wide. (See Fig. 7.) The tubers lose practically all pink or red color, assuming one of creamy yellow. The skin is often full of numerous short, narrow cracks. Infected tubers seldom develop knobs or second growth, a common habit of normal tubers of this variety.

Irish Cobbler.—As this is a deep-eyed variety, the development of shallow eyes is a very reliable symptom of the presence of the spindle-tuber disease. In the advanced forms the tubers are extremely elongated and rough with a large number of eyes, all of which are shallow and many of which are bulging (Fig. 8). In normal tubers the apical eyes are

FIG. 8.—Irish Cobbler potatoes—elongated tubers are infected with spindle-tuber, other tubers are healthy.

FIG. 9.—Downing potatoes—elongated tubers are spindle-tubers; blocky type tubers are normal healthy tubers.

very deep, but in tubers seriously infected with this disease they are never sunken. The skin color changes from a creamy white to a deeper yellow.

Downing.—Infected plants of this variety very generally produce only one stem per hill instead of the large number (3 to 8) produced by normal plants. The plants are also very erect, in striking contrast to the spreading habit of normal plants. The seriously infected tubers are very long and cylindrical with many eyes, in contrast with the blocky type and very few eyes of healthy tubers. The number of tubers per hill is very greatly reduced, because of the single stem habit of the infected plants (Fig. 9).

Russet Rural New Yorker.—In this variety infected tubers frequently do not develop russeting or if so only in blotches. (This is also the case with the Russet Burbank.) The tubers are also quite subject to growth cracks and are much elongated and very rough (Fig. 10).

FIG. 10.—The effect of spindle-tuber on Russet Rural New Yorker potatoes. Healthy tubers at left; diseased tubers at right.

TRANSMISSION OF THE DISEASE

The spindle-tuber disease is carried over from year to year in the tubers. Being of an infectious nature it can be transmitted from a diseased plant to a healthy one. In this respect, it is similar to the other degeneration or virus diseases such as mosaic and leaf roll. In potato fields the disease is transmitted by means of insects, principally plant lice (aphids), which are very small, green, sucking insects. In spite of the fact that very few of these plant lice occur in western Nebraska, the spindle-tuber disease has been found to be extensively transmitted in western fields. Therefore, quite

probably some other agency is the medium responsible for a large part of the transmission occurring in that section.

TRANSMISSION EXPERIMENTS

In experimental plantings the spindle-tuber disease was transmitted to normal plants when diseased plants were adjacent in the row, when they were in the adjoining row, or when a number of rows away. The percentage of infection and severity of the disease increased as the number of infected plants increased or as the distance between plants was decreased.

When diseased and normal seed pieces were planted alternately in the row, the following year the progeny of the normal plants produced a crop in which 97 per cent of the plants and all of the tubers showed the disease symptoms to such an extent that the tuber type was only 2.61 and the total yield only 93.3 bushels per acre (or only 23.4 per cent of the yield from healthy stock). The progeny of another set of plants from the same seed tubers but protected from infection produced healthy normal plants only, which bore tubers with an average type of 7.9 at the rate of 399.5 bushels per acre.

When infected plants were in adjacent rows on both sides, the progeny of normal plants showed a higher percentage of infection than when infected plants were adjacent on only one side. As the distance from infected stock increased, the percentage of diseased plants in the progeny decreased. The progeny of Triumph potatoes produced in a row adjacent to infected stock showed the spindle-tuber disease symptoms in 70.3 per cent of the plants as compared with 62.4 per cent infection in the case of those raised in the second row and 53.6 per cent in those from the third row, while those from the lot grown in a normal field of healthy plants showed only 3.6 per cent infection.

The disease has been known to spread across many rows of potatoes in commercial plantings. In northern Maine it was found to have spread across at least 49 rows.

The disease has been transmitted experimentally from diseased to healthy tubers by means of tuber grafts. The progeny produced from such artificially infected healthy tubers developed symptoms as advanced as those shown by the tubers originally used as the source of infection.

It has recently been shown (Murphy in Ireland) that leaf roll can be transmitted in the bin from sprouts of diseased

tubers to sprouts of healthy tubers by certain insects. It is quite possible that similar transmission may occur with the spindle-tuber disease.

RATE OF INCREASE OF THE DISEASE

When a lot of seed is once infected, the spindle-tuber disease increases rapidly because of the fact that it is carried over in the seed tubers and is also very easily transmitted in the field. In some commercial lots, the disease has been observed to increase from two to ten fold or more by the end of the second season after infection took place. Under conditions very favorable for the spread of the disease, if 1 or 2 per cent of the plants show infection, 100 per cent of the plants and tubers may become infected before the end of the season.

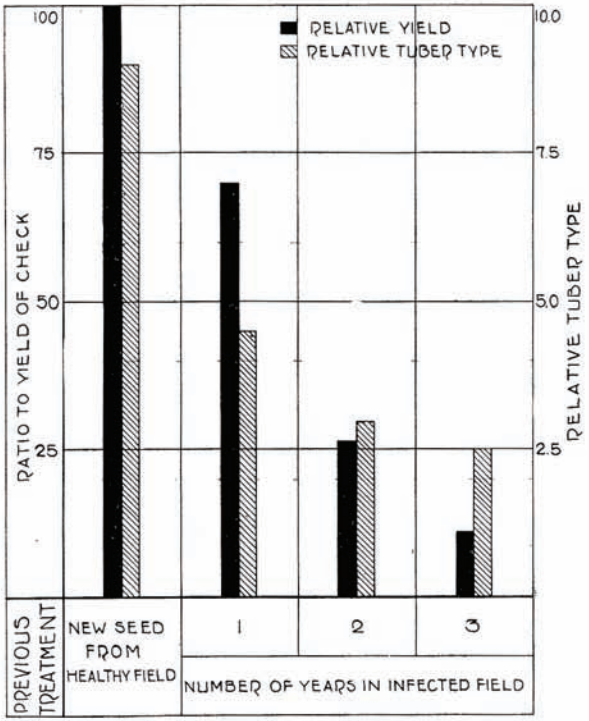


FIG. 11.—When grown in a field containing many plants infected with spindle-tuber, new healthy seed became infected, as shown by a lower yield of poorer type potatoes with each succeeding year.

Whenever healthy lots of potatoes were brought into an infected field the stock became infected. The following year it produced a considerable percentage of infected plants and received more infection from the surrounding diseased plants. Consequently the disease increased both in extent and severity. This is graphically shown for one lot of potatoes in Fig. 11. With each additional year of culture in the infected plat the degree of infection and severity increased as shown by the declining average tuber type and yield. As the market quality was damaged in proportion to the tuber type, the lot was really unprofitable for seed purposes after being grown in the infected plat one season. This record is typical of a large number of lots that have been observed in both irrigated and dry land fields.

RELATION OF ENVIRONMENT TO TRANSMISSION AND INCREASE

The disease does not spread with equal rapidity under all environmental conditions. The temperature, amount of moisture, type of vine growth, and quantity and kind of insects present all may be of importance in this connection.

DRY LAND VS. IRRIGATION IN WESTERN NEBRASKA

In a number of experiments, many of which have been reported elsewhere (Nebraska Research Bulletins 24 and 32), spindle-tuber was found to have spread more rapidly in the irrigated fields than in the dry land fields. In some seasons very little transmission seems to have taken place in dry land fields, but in most seasons there was evidence of some transmission. Thruout these experiments there is much indication that considerable transmission occurred every year in the irrigated fields.

It is believed that the greater spread of the disease in irrigated fields is due to the more rank vine growth which provides a better habitat for insects. Small, weak plants from severely infected seed pieces do not come thru the soil until very late in the season. These serve as unsuspected sources of infection for the adjacent luxuriously-growing healthy plants. In dry land fields conditions are often less favorable for growth and consequently many of these severely infected seed pieces probably do not produce plants, and hence are eliminated as a source of infection. Furthermore, since the size of the tubers decreases as the severity of the disease increases in dry land fields, many of these severely infected plants cannot develop any tubers large enough to harvest.

These same seed pieces would produce only a few small tubers if planted under the more favorable soil conditions in an irrigated field.

STRAW MULCHING VS. CULTIVATION IN EASTERN NEBRASKA

In eastern Nebraska the growing of small areas of potatoes under a straw mulch has long been a fairly common practice. In previous bulletins issued by this station,[1] it was reported that potatoes grown under a straw mulch were equally as good for seed purposes as those from the north, while potatoes grown by ordinary cultivation methods were about 25 per cent less productive.

The progeny of Early Ohio potatoes raised under a straw mulch at Lincoln showed less infection of this disease in plant tops and tubers than did the progeny of some of the same seed produced by ordinary cultivation methods. The tuber type of the progeny of the mulched stock averaged 7.47 as compared with 4.34 for the progeny from the cultivated stock and 6.97 for the tubers from the check raised from the original western Nebraska seed. The yield per acre for these lots was 316.6 bushels, 207.1 bushels, and 306.7 bushels respectively.

TIME OF PLANTING

Early planting of seed infected with spindle-tuber disease frequently results in the appearance of a higher percentage of infected plants and tubers the following year. This has been observed numerous times in commercial fields. Early Ohio potatoes planted at Lincoln on April 10 developed more extensive spindle-tuber symptoms in the crop raised from the progeny than was the case with stock planted May 18. The average tuber type of the April 10 progeny was 3.51 and that of May 18 was 7.76, while the check stock raised from the original western seed averaged 8.87. The yield from these respective lots was 185.8 bushels, 325.4 bushels, and 378.2 bushels per acre.

Probably the development of the smaller amount of spindle-tuber disease in the late planted lots is due to the fact that transmitting insects are less numerous late in the summer when these plants make most of their growth and also because the plants are in the field (and consequently exposed to infection) for a shorter period of time.

[1] Neb. Exp. Sta. Bul. 146, Dec., 1914. Home Mulched vs, Northern Seed Potatoes for Eastern Nebraska, by R. A. Emerson. Popular edition by R. F. Howard, April, 1915.

TIME OF HARVESTING

The length of time during which a lot of potatoes is in a field can be reduced by early harvesting as well as by late planting. The progeny of normal Triumph potatoes (growing in an infected field) harvested on August 20 produced a crop with an average tuber type of 5.62 as compared with 2.62 for the crop from the progeny of the lots harvested on October 10. The check lot, grown in an isolated plat, the next year produced tubers with a type value of 9.43. The percentage of infected plants was also lower in the case of the early harvested lots. Apparently by early harvesting some infection was avoided, but this was relatively slight when compared with the check grown in a field of normal potatoes. Similar results were observed with Early Ohio potatoes grown at Lincoln and harvested at different dates.

SPINDLE-TUBER CONTROL

Some of the methods applied in endeavoring to control the spindle-tuber disease were: Selection of good type seed tubers, removal of diseased plants by roguing, early and late planting, early and late harvesting, various cultural methods, and the growing of seed potatoes in isolated fields in various parts of the state. Any one of these methods used alone has not been as satisfactory as combinations of several methods.

A selection of the best type tubers from a severely infected lot of seed was very unsatisfactory, as shown in Fig. 12. The good type tubers produced only a slightly better yield of inferior tubers than did the culls. Both lots were very inferior when compared with the good results secured from the original uninfected seed. When plants become infected late in the season, the tubers become infected but not sufficiently so to cause them to develop the disease symptoms. Consequently, as in this case, the good type tubers selected out of an infected lot are infected and consequently they will produce diseased low-yielding plants with poor type tubers.

In the case of relatively healthy stock containing only a very small percentage of spindle-tuber and that of a mild form, tuber type selection is desirable. Tubers with prominent, well-developed, and somewhat sunken eyes (especially on apical end), and having the characteristic round shape with normal color, should be selected. Tubers of a blocky or tapering shape with shallow eyes should be avoided. There is also slightly less danger in selecting the medium

and large-sized tubers, avoiding the little potatoes (under $1\frac{3}{4}$ inches), as tuber characteristics cannot always be readily observed with such small tubers. Such selection should be followed by proper isolation from diseased stock and roguing, as discussed later.

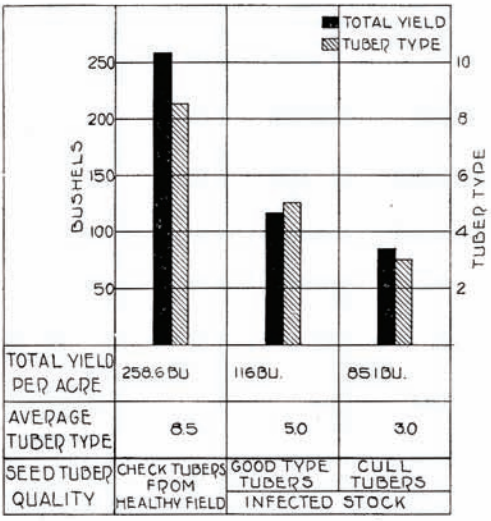


FIG. 12.—When a lot of seed is infected with spindle-tuber, selection of good type tubers for seed is of no practical value.

It has been shown (page 17) that late planting is of some value in avoiding infection. This is a very practical method in western Nebraska. It also generally results in the production of better type tubers that are very seldom scabby. However, special precautions must be taken to store the seed under proper conditions till planting time and to conserve the soil moisture so that the seed will grow promptly. Moisture can best be conserved in dry land regions by early plowing and subsequent diskings to keep the soil loose and fallow. Plantings made between June 15 and July 1 are considered as late plantings in western Nebraska. Plantings later than that are hazardous. Such late planted stock may be very immature and tender at harvest time and must consequently be handled carefully to prevent injury. In the central and eastern part of the state late planting is less certain, due to the unfavorably high temperatures prevailing during June and early July when such plantings should be made.

Early harvesting has been found to be of some value in reducing the amount of infection. It is, however, of doubtful practical value because of the difficulty involved in storing potatoes for the longer period. If very good storage facilities are available it is worthy of trial. If the stock was planted early, then early harvesting should be seriously considered.

It has been shown that under some cultural conditions the disease spreads more easily than under others (irrigation compared with dry land, and straw mulching compared with cultivation). This, however, does not mean that good seed potatoes cannot be produced under the less favorable conditions. It means that under such conditions the control of the disease will be more difficult and requires more painstaking effort. Consequently, under some conditions it might be more practical to buy seed potatoes from the grower more ideally located.

If a lot of seed contains a low percentage of spindle-tuber (5 per cent or less) it may be possible to reduce this percentage or prevent an increase, by thoro roguing (removal of all diseased plants) early in the season and at frequent intervals thruout the season. As soon as plants are discovered that show even the mildest symptoms they should be removed. Our experiments have shown that the disease is sometimes transmitted very early in the season. Therefore, if roguing is delayed many plants will have been infected; and even tho later roguing is thoro, a large number of diseased plants may appear the next season. This was the case with a commercial strain that was planted in two fields. One was rogued early and thoroly at intervals. The other field was rogued thoroly but not till late in the season. The following year in a comparative trial plat the lot from the early-rogued field produced only 1.7 per cent of mild spindle-tubers, whereas that from the late-rogued lot produced 19.9 per cent of more severely infected spindle-tubers.

Roguing was effective in controlling the disease in both dry land and irrigated fields. A good strain of Triumph potatoes grown in a rogued dry land field produced from 1.0 to 1.7 per cent spindle-tubers the following year and that from an irrigated rogued field 1.8 per cent to 2.5 per cent. Tubers of this same strain when grown in both dry land and irrigated unrogued plats containing diseased plants developed the disease the following year in 25 per cent to 75 per cent of the plants.

With lots containing a high percentage of infected stock, roguing has been a failure. (See Fig. 13.) In one commercial lot containing 14 per cent of spindle-tuber in the seed stock, the disease was so well disseminated, in spite of careful systematic roguing which removed about 25 per cent of the plants, that the following season 23.2 per cent of the tubers showed advanced symptoms. In the case of the experimental lot referred to in Fig. 13, the spindle-tuber increase was much greater.

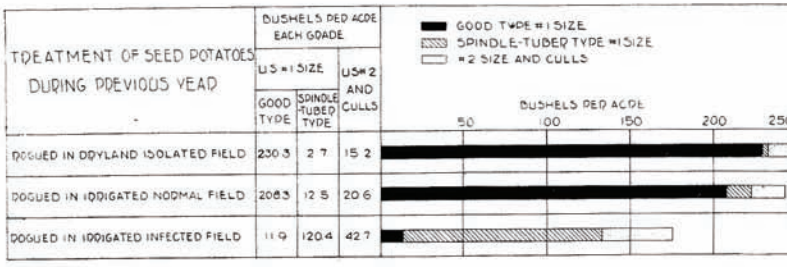


FIG. 13.—In isolated fields containing a low percentage of spindle-tuber, removal of diseased plants (roguing) is a practical control measure. The normal irrigated field referred to in this chart contained somewhat more spindle-tuber plants than did the dry land plat, hence progeny produced more spindle tubers. The lot grown in the infected field was commercially worthless.

The most practical method now known is to secure a lot of potatoes containing no spindle-tuber or as little as possible, and then to select the best type tubers for planting a seed plat isolated by at least 300 feet from any other potatoes. This seed plat should be thoroly rogued a number of times thruout the season, removing any suspicious looking plants that might be infected.

[10M]